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WATER HEATING APPARATUS

This invention relates to water heating apparatus.

More particularly, the invention relates to water heating apparatus which can be used to provide a hot water supply such as a domestic hot water service. The apparatus also has provision for hydronic heating, although this need not be used in some circumstances.

The general object of the invention is to provide a highly efficient hot water heating apparatus.

According to the present invention there is provided water heating apparatus including:

a storage tank for storing heated water;

a gas burner assembly for heating water in the tank;

the gas burner assembly including:

a housing;

a gas burner in the housing;

at least one passage through the housing; and

mounting means for mounting the housing in the tank such that, in use, it is immersed in water within the tank and wherein, when the gas burner is operated, the temperature of the housing rises and heat transfer to the water in the tank occurs and a convection current in said water flows through said at least one passage to thereby increase heat transfer to the water.

Preferably, there are a plurality of said passages extending through the housing.

Preferably, the housing includes a cylindrical housing sidewall and top and bottom housing end walls and wherein the passages are defined by tubular elements which extend between the housing top and bottom walls.

Preferably the bottom wall is inclined at an angle to the horizontal so that gas bubbles tend not to be trapped thereunder. Trapped air and/or steam bubbles could cause localised heating and/or corrosion.

Preferably further the storage tank includes one or more coils located within the storage tank and above the gas burner assembly. In use cold water from a mains supply is coupled to the lower end of the coils so that the water circulated therethrough absorbs heat from the water in the tank. This causes cooling of the water adjacent to the coils and if sufficient heat is extracted cool convection currents will be established. A temperature sensing element can be located in a position where it is impinged on by the cool convection currents in order to cause activation of the gas burner. The gas burner is made sufficiently large that it is able to provide sufficient heating capacity to the water within the tank so that the apparatus functions as a continuous water heater should substantial amounts of hot water be required. It will be appreciated that the apparatus of the invention functions partly as a storage type hot water system and a continuous hot water system.

The apparatus used above can be used in conjunction with a solar energy collection system. Basically, the solar energy system can be used as a pre-heater for water entering the coil of the apparatus defined above.

According to this aspect of the invention there is provided a gas/solar hot water heating apparatus including:

water heating apparatus as defined above;

a solar collector panel;

a solar storage tank;

circulating means for circulating water from the solar storage tank to the panel;

a heat exchanger in the solar storage tank; and

said coupling means being operable to pass water from the mains water supply through the heat exchanger in said solar storage tank prior to passing through the heat exchanger in said storage tank.

Preferably, the solar storage tank is located beneath the storage tank and within a single housing.

In the preferred form of solar collector panel, a flue gas chamber is provided so that flue gases can be circulated through the panel for recovery of heat therefrom.

The invention also provides a gas/solar water heating system including:

a gas fired water heater having a flue;

a solar collector panel;

a solar storage tank;

circulating means for circulating water from the solar storage tank to the panel;

a heat exchanger in the solar storage tank; and

said solar collector panel including a flue gas chamber therein and flue gas ducting means for coupling said flue to the flue gas chamber, the arrangement being such that water circulated through the panel absorbs solar energy and heat energy from flue gases entering the chamber.

The gas/solar water heating system defined above may be used in conjunction with a motor generator set. In this case the exhaust gases from the motor can be circulated through the solar panel in order to extract heat therefrom.

The invention also provides a hot water heating apparatus including:

a gas/solar water heating system as defined above;

an internal combustion engine having an exhaust; and

exhaust gas duct means for directing exhaust gases into said flue gas chamber whereby the water circulated through the panel absorbs heat from said exhaust gases.

The invention also provides a solar collector panel which includes a first chamber for circulating water to be heated therethrough and a second chamber for circulating flue or exhaust gas therethrough, the two chambers being in thermal contact with one another so that heat from the flue gas or exhaust gas can be absorbed into the water in the first

chamber.

The invention will now be further described with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of water heating apparatus constructed in accordance with the invention;

Figure 2 is a more detailed schematic view showing the internal structure of the apparatus;

Figure 3 is a more detailed sectional view through the lower part of the apparatus showing the burner assembly;

Figure 4 is an underside view of the burner assembly;

Figure 5 is a schematic sectional view taken along the line 5-5;

Figure 6 is a side view of the fan;

Figure 7 is a plan view of the fan;

Figure 8 is a control circuit for control of the apparatus;

Figure 9 is a schematic view of a solar/gas water heating system;

Figure 10 is a control circuit suitable for controlling the solar heating apparatus of Figure 9;

Figure 11 shows a modified gas/solar system;

Figure 12 shows a further modified gas/solar water heating system;

Figure 13 is a schematic sectional view through a combination unit having a water heater and solar storage tank;

Figure 14 is a schematic view of an electric water heating apparatus;

Figure 15 is a schematic view of a modified form of water heating apparatus; and

Figures 16, 17 and 18 show details of a preferred form of solar absorbing panel.

Figure 1 is a schematic view of a water heating apparatus 2 constructed in accordance with the invention. The water heating apparatus includes a main tank 4 located within a sheet metal housing 6. Located within the tank 4 is a gas burner assembly (not shown in Figure 1) which is supplied with a combustible mixture of gas and air. Located within the tank 4 is a coil assembly 8 which in the preferred form of the invention is in the

form of two helical coils of copper tubing which are connected in parallel so as to reduce resistance to water flow therethrough. The coil assembly 8 includes inlet couplings 10 and 12 which are connected to a cold water inlet line 14. The inlet line 14 is connected to a cold water inlet coupling 16 which is accessible from the exterior of the housing 6. In use a mains supply is connected to the coupling 16. The coil assembly 8 includes outlet couplings 18 and 20 which are connected to a high temperature outlet line 22. The line 22 includes a T-coupling 24 which is connected to a high temperature outlet line 26 which terminates at a high temperature outlet coupling 28. The outlet coupling 28 is provided so as to utilise high temperature water which might be required in some circumstances. As will be described in more detail below, the water within the main tank 4 is under pressure and can be heated to above 100°C, typically the operating temperature being in the range 80°C to 90°C but temperatures of 110°C could be selected in some circumstances. High temperature water at about this temperature is thus available from the coil at the high temperature outlet coupling 28, assuming that water flowing in the coil assembly has sufficient time to reach or substantially reach the same temperature as the water within the main tank 4. The water in the tank 4 does not boil because it is under pressure, say 50 psi, and therefore 110°C is well below the boiling point for water at this pressure.

The apparatus includes a mixing valve 34 which receives high temperature water on the line 22. It also receives cold water via line 36 which is connected into the cold water inlet line 14 via T-coupling 38. The mixing valve includes an outlet line 40 which extends to the housing 6 and terminates in a hot water outlet coupling 42. The mixing valve 34 is arranged to mix cold water from the mains supply with the high temperature water from the coil assembly 8 so as to produce water at a temperature which is suitable for use in bathrooms and kitchens. Typically this water is in the range 40°C to 60°C and preferably 45°C.

The apparatus 2 includes a header tank 44 which is located within the housing and above the main tank 4. The main purpose of the header tank 44 is to enable any air bubbles in the main tank 4 to move into the header tank 44 and to control the operating pressure of the main tank 4, as will be described in more detail below.

As the main tank 4 can be operated at above atmospheric pressure, say at 50 psi, it needs to be of relatively robust construction. Normally, it would be of welded steel construction having a cylindrical sidewall 46, a top wall 48 and a bottom wall 50. Because the main tank 4 is made of steel, it would be susceptible of rusting or corrosion if oxygen or air were dissolved in the water within the main tank or otherwise admitted to the main tank. Normally, however, the water within the main tank 4 is a fixed body of water and any oxygen therein would cause very limited corrosion before it were exhausted. This applies even where the water within the main tank 4 is circulated in an hydronic heating system because essentially the same volume of water is maintained in the system. Nevertheless, fresh water may be occasionally introduced into the main tank 4 to compensate for any water which may be lost due to leakage or the like. Accordingly, the header tank 44 is provided in order to collect any gases which may be present in the main tank 4. The header tank 44 can be made from non-corrosive material such as copper. The header tank 44 may have a capacity of say five litres in circumstances where the nominal capacity of the tank 4 is 130 litres. The top wall 48 of the main tank 4 includes a coupling 52 to which is connected a transfer line 54, the other end of which is connected into the top of the header tank 44. It will be seen that the top wall 48 is inclined to the horizontal so that any gas bubbles in the main tank 4 will migrate towards the coupling 52 and be transported to the header tank 44. The header tank has an outlet near its bottom connected to a return line 56 which serves to permit water from the header tank 44 to return to the main tank 4.

The high temperature outlet line 22 includes a T-coupling 58 which is connected to a pressure relief valve 60. A pressure relief line 62 extends from the valve 60 to an upper part of the header tank 44 as shown in Figure 1. Alternatively, the pressure relief line 62 can be diverted directly into line 64 bypassing the header tank as shown in Figure 2. The header tank 44 includes a pressure relief line 64 which is coupled to a second pressure relief valve 66 which has an outlet 68 external to the housing 6. The second pressure relief valve 66 is arranged to relieve pressure within the header tank 44 when the pressure therein exceeds a predetermined value, say 50 psi. This therefore determines the operating pressure within the main tank 4. The first pressure relief valve 60 is arranged to relieve

water pressure within the coil assembly 8 when it exceeds a predetermined value. This can occur when cold water is admitted to the coil assembly 8 and hot water flow is stopped. Thermal expansion occurs in the water in the coil assembly because of heat absorption from the water in the main tank 4. The first pressure relief valve 60 can be set at say 200 psi so that it will relieve excess pressure from within the coil assembly 8 when the pressure therein reaches 250 psi (because it also needs to overcome the internal pressure within the header tank 44).

As mentioned above, the water within the main tank 4 can be used for hydronic heating. Accordingly, the tank 4 includes a heating water outlet line 70 connected to a coupling 72 accessible from the exterior of the housing 6. The apparatus also includes a heating water return line 74 connected to a coupling 76 which is also accessible from the exterior of the housing 6. The coupling 72 and 76 permit connection of the apparatus 2 to a space heating system which may include radiating panels and/or fan coil units for extracting heat from the water within the main tank 4. In hydronic heating systems the water which is circulated is essentially a fixed volume of water and therefore corrosion of the main tank 4 and the hydronic heating elements is not normally a significant problem.

The apparatus 2 includes a gas inlet coupling 78 connected to a gas supply line 80. The gas inlet line 80 supplies gas for the burner assembly, as will be described in more detail below. Air for combustion is admitted to the housing 6 through vents 82. The housing 6 has a top wall 83 which includes a flue housing 84 having vents 86 therein for discharge of flue gases from the gas burner.

Figure 2 schematically illustrates more details of the internal structure of the apparatus 2. First of all, it will be seen that a layer of insulation 90 is located between the outer surface of the main tank 4 and the housing 6 so as to avoid heat losses from the main tank. Located within the housing and above the main tank 4 is a fan 92. The fan 92 draws air and gas into its input and its outlet is connected to a gas air supply duct 94. Admission of gas to the fan 92 is controlled by a gas control valve 96 which receives gas from the gas supply line 80.

The apparatus includes a burner assembly 100 which is located in the lower part of the main tank 4 and in use is completely immersed in the water within the main tank. Located within the burner assembly 100 is a gas burner 102 which is coupled to the duct 94. A flue pipe 104 extends from the burner assembly through the interior of the main tank 4 and extends through the top wall 48 to the flue housing 84. The flue pipe 104 has an inclined opening 106 which faces away from the vents 86 so as to avoid the possibility of rainwater or the like entering the flue pipe 104 and the burner assembly.

As the interior of the main tank 4 is subject to above atmospheric pressures, it is desirable that the top and bottom walls 48 and 50 be reinforced so as to prevent buckling thereof under the internal pressure. The illustrated arrangement shows a convenient way in which this may be achieved. In this arrangement there are four reinforcing rods 108, 110, 112 and 114. The lower ends of the rods are welded to the top and bottom walls 48 and 50 so as to restrain outward deformation of these walls. Alternatively, a single larger diameter rod could be used.

The high temperature outlet line 22 from the coil may include a one-way or check valve 116 so as to prevent backflow of water into the line 22.

The apparatus may also include an additional outlet for providing sterile water which can be used for drinking or beverages. Accordingly, the apparatus includes a sterile water outlet line 118 connected to a sterile water outlet coupling 120. The sterile water outlet line 118 may include a control valve 122 which operates only to permit flow therethrough when the water in the coil assembly 8 is above a predetermined temperature, above 100°C. The apparatus may also include a further high temperature outlet line 124 connected to an outlet coupling 126 for providing high temperature water directly from the coil assembly 8. Where the operating temperature is at or above 100°C this can be used as a supply of boiling water. In such a case, some cold water should be used to reduce the temperature of the water supplied to the high temperature outlet coupling 28 so that the water is delivered at 60°C to 80°C. The apparatus includes a bypass line 125 including a valve 127. The valve 127 is preferably solenoid controlled so that it is closed when the

temperature of water at the coupling 28 falls below a predetermined value, say 60°C. In the illustrated arrangement, part of the inlet line 14 is widened and forms a water jacket 128 for the sterile water outlet line 118 so that useful heat can be extracted therefrom and inputted into the water flowing in the coil assembly 8. Usually cooling of the sterile water is also required.

The heating water outlet line 70 may include a valve or tap 130. When the main tank 4 is being initially filled, a mains supply can be connected to the coupling 72 and the valve 130 opened to fill the main tank 4 and header tank 44 to a level indicated by line 132. After initial filling, the valve 130 can be closed and the coupling 76 also stopped. If, however, hydronic heating is to be utilised the valve 130 is opened after connection to the hydronic heating components. In the illustrated arrangement, the line 134 indicates a supply line to the hydronic components and a circulating pump 136 may be provided in this line.

The apparatus may also include an electric heating element 140 located within a tube which extends laterally into the main tank 4 a short distance above the bottom wall 50. The purpose of the electric element 140 is to enable heating of the water within the main tank 4 in emergency circumstances in the event that the gas supply becomes interrupted. Typically the heating capacity of the element 140 is 2.5kw.

The apparatus includes a temperature sensing element 150 which is arranged to provide input signals to the gas control valve 96 which controls flow of gas to the fan 92 and the operation of the fan 92. Basically, when the temperature sensor 150 senses a temperature below its set operating temperature, say 80°C to 90°C, it has contacts which close and this causes the gas control valve to supply gas to the fan 92 and to operate the fan. This causes a flow of a combustible gas air mixture through the duct 94 to the burner 102. The control valve 96 also causes ignition of the gas so that heating will occur. The gas burner assembly 100 includes a plurality of water passages 152 therethrough. When heating occurs within the burner assembly 100, convection currents will be established causing rising heated convection currents to flow upwardly through the coil assembly 8

where heat transfer will take place to water within the coil assembly 8. This causes consequential cooling of the water within the main tank 4, thereby causing cooler, downwardly flowing convection currents to occur near the sidewalls of the main tank 4. This cooler water will then be drawn into the lower ends of the passages 152 through the burner assembly 100 and reheated. These convection flow paths within the water in the main tank 4 provide for good heat transfer. Heat transfer also takes place from flue gases flowing in the flue pipe 104.

The temperature sensing element 150 is located at a level just below the bottom of the burner assembly 100 and relatively close to the sidewall of the main tank 4. This ensures that it is in the path of downwardly flowing cooler convection currents. When these cooler convection currents impinge on the temperature sensing element 150 they will cause its contacts to close or remain closed for operating the gas control valve 96. If the temperature of the water within the main tank 4 rises to above the operating temperature of the sensing element 150, its contacts will open and the control valve 96 will stop operation of the fan 92 and supply of gas to the fan. The arrangement has the advantage that once the water within the main tank 4 has reached operating temperature, limited amounts of water can be drawn from the outlets 28 and 42 without creating large convection currents which would reach the sensing element 150. Thus limited amounts of water can be taken from the apparatus without activating the gas burner 102. If, however, large quantities of heat are extracted from the water within the main tank 4, such as when a bathroom shower or the like is operated, then large convection currents will flow downwardly and will impinge upon the temperature sensor 150. This will quickly activate the burner 102 to therefore ensure that the temperature of the water within the main tank 4 is not significantly reduced.

Figures 3 and 4 schematically illustrate the burner assembly 100 in more detail. It will be seen that the burner assembly includes a burner housing 170 having a cylindrical sidewall 172, top wall 174 and bottom wall 176. The housing includes a mounting tube 178 which is welded to the sidewall 172 and is also provided with a flange 180 which permits welding to the inside face of the cylindrical sidewall 46 of the main tank 4. The

top wall 174 includes a flue port 182 into which is welded the lower end of the flue pipe 104.

As best seen in Figures 4 and 5, the burner assembly includes a plurality of convection current tubes 184 which are welded into openings 186 and 188 formed in the top and bottom walls 174 and 176 respectively of the burner housing.

It will be noted from Figure 3 that the central axis 189 of the housing 170 is inclined to the vertical. Preferably the inclination is in the range from 1° to 5° and preferably 2½°, the inclination being exaggerated somewhat in Figure 3 for clarity of illustration. The tubes 184 define the convection flow passages 152 described previously. It will be also seen that the reinforcing rods 108, 110, 112 and 114 pass through the tubes. This enables them to be connected at central areas of the top and bottom walls 48 and 50 of the main tank 4 where support is most critical. The main purpose of the installation of the burner housing 170 is so that its top and bottom walls 174 and 176 are inclined to the horizontal. It has been found that this avoids retention of gas bubbles, particularly beneath the bottom surface 176 which might occur if it were horizontally disposed. Accumulation of gas bubbles beneath the bottom wall 176 could cause localised overheating which in turn may produce and sustain localised boiling and excessive noise and vibration. Thus, the inclination of the surfaces is a simple but effective way of overcoming serious problems which may occur in practice.

As the burner housing 170 is subjected to the full internal pressure within the main tank 4, it must be of relatively robust construction and the provision of the tubes 184 also serve to strengthen the housing. The bottom wall 176 may be additionally strengthened by a reinforcing bar 190 which is welded to the underside of the bottom wall 176, as shown.

As seen in Figure 3, the burner 102 includes a stainless steel tube 200 having a closed inner end 202. The inner part of the body includes a multiplicity of perforations having a size of the order of say 1mm. The tube 200 is provided with a mounting flange 204 which enables it to be connected to the sidewall 46 by means of threaded studs which

project from the sidewall 46 of the main tank. The lower end of the air gas duct 94 is connected to the flange 204 via a gasket (not shown). The arrangement is such that the air gas mixture is admitted to the interior of the tube 200 so that it can escape through the perforations therein. Located adjacent to the exterior of the tube 200 are ignition electrodes 210 and 212 and a flame detection electrode 214. The electrodes are connected by means of conductors 216 which pass through the mounting tube 178 and are coupled to the gas control valve 96. The air gas mixture passing through the perforations forms jets of burning flame which heat the interior of the housing 170. The arrangement has very good heat transfer because the burner assembly 100 is immersed in the water in the tank and convection currents flow through the passages 152 therein to enhance heat transfer.

Figures 6 and 7 diagrammatically illustrate the fan 92 and gas control valve 96 in more detail. It will be seen that the fan 92 includes an outlet 220 which is coupled to an elbow 222 formed at the upper end of the gas air duct 94. The fan is driven by a fan motor located within a fan motor housing 224 located on the side of the fan, as shown in Figure 7. The inlet to the fan is in the form of a venturi 226 which is located generally centrally of the axis of the impeller (not shown) of the fan. Located centrally of the venturi 226 is a gas inlet duct 228 which permits gas such as natural gas or town gas from the valve 96 to be entrained in air flowing into the venturi 226, when the fan motor is operated.

The apparatus includes an over temperature sensing element 230 to sense when excessive temperatures are reached within the interior of the main tank 4. It is preferred that the over temperature sensor 230 is located on the upper surface of the top wall 48 of the main tank 4 and is also connected or close to the flue pipe 104. Normally the sensor 230 will be at about the same temperature as the water in the tank 4 and will therefore be at the operating temperature of the water, say 110°C. If, however, the temperature rises above this point, the sensor 230 will be sensed by the control valve 96 which will then operate to stop the fan 92 and flow of gas to the burner 102. With the over temperature sensor 230 mounted in this position, should an air gap develop in the top of the main tank 4 the temperature will rise because the sensor 230 is in thermal contact with the flue pipe 104. Thus the sensor also indirectly functions to detect the presence of an air gap within

the top of the main tank 4 and to shut off supply of gas in that event. The sensors 150 and 230 are of known type having a fluid filled bulb including a diaphragm coupled to operate contacts of a switch.

The fan 92 can be of a commercially available type, such as a Zeihl Model MVL RG130. This fan produces a flow rate of about 50 cubic feet per minute at an outlet pressure of about 2 inches water gauge. The gas control valve 96 can also be of known type and one suitable valve is made by SIT Model No. 577 DBG. This control valve has all of the necessary functions built into it to control the apparatus 2 including control of the ignition electrodes 210 and 212 and the spark detecting electrode 214.

Figure 8 diagrammatically illustrates the wiring of the gas control valve 96 to other control components in the system. The temperature sensing element 150 includes contacts 231 and 232 which are normally closed when the sensing element 150 senses a temperature below the operating temperature. This provides mains power into the gas control valve 96 to therefore enable operation of the fan 92 and opening of a gas valve (not shown) inside the gas control valve 96. The sensing element 150 has a back terminal 234 which is arranged to be closed when the sensing element 150 senses the correct operating temperature. This deactivates the fan and enables supply of mains electricity to the circulating pump 136 via a manually settable room thermostat 236 or other controller. This configuration ensures that heat from the water within the main tank 4 is only used for hydronic heating at times when the temperature of the water within the main tank 4 is at operating level. Thus, there is inherently a priority given to hot water extracted from the coil assembly 8 over heat required for hydronic heating.

Details of the gas control valve 96 are well known and need not be described in detail. Briefly, the gas control valve 96 has the following operating sequences. When it is first activated, it causes the fan 92 to operate so as to cause purging air to flow through the duct 94 and into the burner housing 170. This removes any exhaust products from previous combustion. Gas is then supplied to the duct 94 and the ignition electrodes 210 and 212 are operated for a predetermined period, say five seconds. If ignition is

successful, this will be sensed by the flame sensor 214 and combustion will continue until the correct operating temperature is sensed by the temperature sensor 150 or an over temperature is sensed by the over temperature sensor 230. If ignition is not successful, the ignition cycle is repeated a predetermined number of times, say three times, and if no flame is detected a Lockout condition is set. This requires a manual override to be applied, as indicated by the override button 238 across the over temperature sensor 230, as shown. The gas control valve 96 may include or have associated therewith an indicating panel which has a Flame Prove indicator lamp 240 which is activated when correct combustion is sensed. The indicator panel may include a Lockout indicator lamp 242 which is illuminated when a lock-out condition is entered.

A prototype of the water heating apparatus has been constructed and has proven to be very efficient. The prototype had the following nominal dimensions:

height of main tank 4	914mm
diameter of main tank 4	560mm
approximate volume of main tank 4	130 litres
height of burner housing 170	406mm
diameter of burner housing 170	406mm
number of tubes 184	20
effective surface area of burner housing 170	1.85 sqm
ratio of burner surface area 170 to volume of main tank 4	0.014 sqm/l
diameter of burner 200	50mm
diameter of reinforcing rods 108, 110, 112, 114	12.7mm
volume of header tank 44	11.5 litres
diameter of flue pipe 104	76.2mm
number of coils in the coil assembly 8	2
number of convolutions of each coil	9
length of each coil	12.19m
external diameter of each coil	12.7mm
gas input	200 MJ/hour
normal water temperature at outlet coupling 28	80-90°C

normal water temperature at outlet coupling 42	45°C
normal water temperature at outlet coupling 126	80-90°C
normal water temperature at outlet coupling 120	20°C
normal water temperature at coupling 72	80-90°C
approximate time to heat water within the main tank to operating temperature	10 mins

The water heating apparatus 2 can be used in conjunction with a solar heating system. Figure 9 illustrates a water heating system 250 which incorporates the water heating apparatus 2 and solar energy collecting apparatus 252 which includes a solar panel 254 and a solar pre-heating tank 256. The tank 256 is connected to an outlet line 258 including a solar circulating pump 260. The pump 260 operates to circulate water from within the tank 256 to the solar panel 254 where it is heated by solar energy and then returned to the tank 256 via return line 262. A cold water mains supply 264 can be connected to the cold water inlet line 36 via a non-return valve 266. The pre-heating tank 256 includes a heat transfer coil 268 through which is circulated cold water from the mains supply 264 via inlet line 270. The outlet of the coil 268 is connected to the water inlet line 14. In this arrangement, the hot or warm water stored in the tank 256 acts as a pre-heater for water circulating through the coil assembly 8 of the apparatus 2. The outlet 68 of the pressure relief valve 66 can be connected to the top of the tank 4 so that water and energy are not lost.

In the system 250, the apparatus 2 can be identical to that shown in Figures 1 to 8. Alternatively, it could be modified by the omission of the header tank 44. In this case an overflow duct 272 is provided to connect the top of the main tank 4 to the top of the pre-heater tank 256. This would accommodate any thermal expansion of the water within the main tank 4. The pre-heater tank 256 may itself have an overflow outlet 274 for discharge of water in the event that it is overfilled or over-pressurised. The solar collecting apparatus 252 may include a temperature sensor 276 mounted in the solar panel 254 and a temperature sensor 278 mounted at the bottom of the pre-heater tank 256. The control circuitry for the solar system 250 is such that when the temperature sensed by the sensor

276 is lower than the temperature sensed by the sensor 278, the solar circulating pump 260 is not operated because this would cause loss of heat. At other times the solar circulating pump 260 can be operated.

Figure 10 illustrates a control circuit 280 which is suitable for controlling the solar system 250. It will be seen that the temperature sensors 276 and 278 are connected to inputs of a comparator 282. The arrangement is such that when a higher voltage level is produced by the sensor 276 compared to that of the sensor 278, a positive voltage is produced at the output of the comparator 282. This is amplified in amplifying stages 284 and then coupled to the input of a drive transistor 286 which activates the operating coil of a relay 288 which controls supply of power to the solar circulating pump 260.

Figure 11 illustrates a modified form of solar system 290 which is similar to that shown in Figure 9. The same reference numerals have been used to denote parts which are the same as or correspond to those of the earlier embodiment. In this arrangement, flue gases from the water heating apparatus 2 are circulated through the solar panel 254 so that the heat from the flue gases can be extracted and absorbed into the water circulating in the pre-heater tank 256. In order to accomplish this, the system 290 includes a flue gas duct 292 which is coupled into the lower end of the panel 254 so that hot flue gases flow in a chamber 294 therethrough. The flue gases are in thermal contact with the circulating water so that the water in the pre-heater tank 256 is heated. The flue gases may then pass to an outlet duct 296 connected to a balanced flue assembly 298. The system may include an air inlet duct 300 which extends from the balanced flue assembly 298 to the air inlet of the fan 92. This arrangement reduces the possibility of unreliable operation of the burner 102 which might be caused by fluctuations in pressure in the flue lines.

In this arrangement, the control circuit 280 for the pump 260 could be linked to the control valve 96 to ensure that optimum performance is achieved. More particularly, the arrangement could be such that the pump 260 is always operated before the burner 102 is activated so that the panel 254 will have water circulated through it before any flue gases enter the chamber 294. This ensures that the panel 254 is not overheated due to the

passage of the flue gases therethrough.

Figure 12 diagrammatically illustrates a modified system 310 in accordance with a further aspect of the invention. This arrangement is generally similar to that shown in Figures 9 and 11 but the system includes an internal combustion engine 312 which is coupled to an electric generator 314 or other device. The generator 314 is arranged to charge batteries 316. The batteries can be used for powering various electrical appliances which are arranged to operate on DC. Alternatively, the batteries 316 could be coupled via an inverter so as to produce 240 volts AC whereby normal domestic electric appliances could be operated.

The internal combustion engine 312 has an exhaust 318 which is coupled via an exhaust line 320 to the solar absorber panel 254. It is preferred that the exhaust line 320 is connected into the flue gas duct 292 which is used to convey flue gases from the burner to the solar absorber panel. The preferred way of connecting the duct 292 to the exhaust line 320 is by forming a venturi 322 in the exhaust line 320 and arranging for the end of the flue gas duct 292 to be located in the venturi 322. The exhaust gases flowing in the line 320 will generally be at a higher pressure and flow rate than the flue products in the duct 292 and by having the venturi coupling, the exhaust gases will tend to entrain the flue products into the larger flow and then into the panel 254. In this way heat energy in the exhaust gases from the internal combustion engine can also be collected by water circulating in the solar panel 254. This arrangement provides for efficient utilisation of the fuel used for the burner assembly 100 as well as the internal combustion engine 312. The system 310 could be advantageously used in remote locations to provide combined electric power, hot water and heating services. The internal combustion engine 312 can also be used to operate on the same gas source which is used for the water heating apparatus 2. It will be further appreciated that the system 310 avoids transmission losses which can be significant in normal electricity distribution systems.

Pollution could be reduced by causing the flue gases from the burner assembly 100 and exhaust gases from the engine 312 to bubble through the water circulating in the panel

254 and at least some of the pollutants will remain in the water. Use of the venturi 322 ensures that an undesirable high back pressure is not created in the flue pipe 104 which could interfere with operation of the burner 102. In this arrangement the pump 260 is operated so as to circulate water through the panel 254 before either the engine 312 or the burner 102 is operated so as to avoid overheating of the panel 254.

Figure 13 shows a combined unit 350 which essentially is the water heating apparatus 2 shown in Figures 1 to 8 having the pre-heater tank 256 located within the same housing 6 and beneath the main tank 4. This arrangement is very convenient and also reduces heat losses which might occur in the various fluid lines and ducts which interconnect the tanks shown in the arrangements of Figures 9, 11 and 12.

A number of enhancements are included in the combined unit 350. In particular, it will be seen that the burner 102 is located near the top wall 174 of the burner housing 170 and the flue pipe 104 is directed downwardly. The flue pipe 104 is located near the lowest point on the bottom wall 176 of the housing so that any condensate will be drained therefrom. The flue gases pass into a flue gas jacket 352 which extends above the pre-heater tank 256 and adjacent to the sidewalls and bottom wall thereof, as shown. This enables heat transfer from the flue gases into the water contained within the pre-heater tank 256. The jacket 352 is connected to a flue pipe 354 which extends to the flue housing 84.

It will be further seen that in the unit 350, the bottom wall 50 of the main tank 4 is inclined somewhat to the horizontal. This ensures that any condensate will tend to run to the lowest point on the bottom wall 50 and then enter the jacket 352 rather than collect on the bottom wall 50. This reduces the possibility of corrosion of the bottom wall 50. Similarly, the tank 256 has a top wall 356 which is also inclined and generally parallel to the bottom wall 50. The tank 256 has a bottom wall 358 which is also inclined so that condensate will drain therefrom to a condensate trap 360. The lower part of the jacket 352 is formed with the condensate trap 360 which has an outlet 362. This arrangement ensures that any condensate from the flue products will be collected in the trap 360 and expelled from the outlet 362 when the trap is full.

The tank 256 may include a central reinforcing rod 364 which extends between the top wall 356 and bottom wall 358 so as to avoid buckling of these parts due to internal pressure within the tank 256. The tank 256 may also include a pressure relief valve 366.

As in the arrangement of Figure 9, when the sensor 276 senses a temperature higher than that at the sensor 278, the pump 260 is operated so that the water within the pre-heater tank 256 is heated by solar absorption. When hot water is drawn from the main tank 4 for hot water or for heating purposes, the water supplied to the coil assembly 8 will be pre-heated in the pre-heater tank 256 because it is circulated through the coil 268. This of course reduces gas consumption.

In the arrangement of Figure 13, the tank 256 may be purposely left with an air gap which is between say 5% and 10% of the volume of the tank 256. The air gap 370 can therefore accommodate thermal expansion of the water within the tank 256 without the need for a separate expansion vessel.

Figures 14 and 15 illustrate how the principles of the invention can be applied to electric water heaters in order to improve the efficiency thereof. The same reference numerals have been used to denote parts which are the same as or correspond to those of earlier embodiments. In this arrangement, the heater is filled so as to leave an air gap 370 which can accommodate thermal expansion of the water within the main tank 4. The tank includes a filling line 382 to which a supply of cold water can be connected for initial filling of the tank. The upper part of the tank includes an inspection opening 384 which defines the upper level of the water within the tank and also enables an operator to observe the level of water within the tank. After initial filling the line 382 and opening 384 are both closed.

The heater 380 includes a second electric heating element 386 and a second temperature sensor 388. In normal operation, the element 140 is operated so as to heat the water within the tank. The element 140 is subject to control of the first temperature sensor 150 which is located at a level beneath the element 140 and generally below the coil

assembly 8. When cold water circulates through the coil assembly 8, it is heated. This causes cool convection currents to flow downwardly. When the convection currents impinge on the temperature sensor 150, the element 140 is activated. If cooling continues sufficiently, the cool convection currents will impinge on the second sensor 388 and this will cause operation of the second element 386.

Figure 15 is a diagrammatic cross-sectional view which shows how the element 140 may have additional electric heating elements 390, 392 and 394 located beside it for additional energy input to the water within the tank.

Figures 16 to 20 show the preferred form of solar panel 254 which can be used in the system 290 shown in Figure 11. This arrangement absorbs heat from the flue gases from the burner 102.

Figure 17 shows the components which make up the panel 254 in a schematic exploded view. The components include the glass sheet 400 beneath which are located upper, intermediate and lower stainless steel sheets 402, 404 and 406. The upper sheet 402 is pressed so as to have laterally extending indentations or grooves 408 thereon. Normally these are about 3mm deep. The edges of the upper sheet 402 are formed with edge flanges 410 to facilitate joining of the upper sheet 402 to the intermediate sheet 404 by means of welding or the like. When the sheets 402 and 404 are joined, a water cavity 412 is defined therebetween, as shown in more detail in Figure 18. The edges of the intermediate sheet 404 are formed with downturned flanges 414 whereas the edges of the lower sheet 406 are formed with upwardly facing channels 416. The underside of the intermediate sheet 404 has a plurality of U-shaped channel sections 418 connected thereto by spot welding or the like. The lower sheet 406 is joined to the intermediate sheet 404 by spot welding or the like. The flanges 414 and the channels 416 combine to form an inlet manifold 420 and outlet manifold 422. The manifolds 420 and 422 extend along respective sides of the panel and the hot flue combustion products from the water heater 2 are introduced into the manifold 420 and then flow through a gas cavity 424 defined between the intermediate and lower sheets 404 and 406, which remain spaced apart by the channel sections 418. The

flue gases transfer heat to water within the water cavity 412 by conduction and the cooled flue gases are expelled through the manifold 422.

An insulation layer 426 is provided so as to be located beneath the lower sheet 406. The insulation layer 426 is provided with rebates 428 along its lateral edges so as to accommodate the manifolds 420 and 422 in the completed assembly as shown in more detail in Figure 18.

The panel includes a base 430 which can be formed from sheet metal such as galvanised iron. Its edges are formed upwardly so as to define sides 432 of the panel. The sides are shaped so as to define inwardly facing grooves 434 for receipt of the glass sheet 400.

The top surface of the upper sheet 402 is preferably treated so that it is absorbent. This may be done by heat treatment of stainless steel to make it selectively absorbent of solar energy, in a known manner. Alternatively, absorbent coatings may be applied thereto.

This arrangement provides an inexpensive solar panel which has a water cavity 412 for heating water circulated therein and a gas cavity 424 for transferring heat from the flue gases to the water circulating in the water cavity 412.

Many modifications will be apparent to those skilled in the art without departing from the spirit and scope of the invention.

For instance, in the arrangement of Figure 13, the burner assembly 100 includes a gas burner 102. In a modified arrangement the burner 102 could be omitted and hot gas or liquid, which would normally be wasted, could be circulated through the housing 170 so that heat therefrom is extracted for heating of the water within the tank 4. The waste gas or liquid could be from a boiler, engine or other device which produces hot gases. This would be particularly suitable in industrial applications where useful heat can be extracted from hot gases which would otherwise be lost to the atmosphere.